Seismic performance of adobe buildings

A presentation in Three Acts

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Act 1

The Perverse Combination
Humans have been building with earth all over the world for thousands of years

Courtesy of Hubert Guillaud

Djenné, Mali
Many developing countries where building with earth is common are located in seismic areas.
Earthen constructions and earthquakes are a 
perverse combination

Peru, 2001

Pakistan, 2005

China, 2010
Unreinforced earthen constructions collapse during earthquakes because earthen material is heavy, weak and brittle.
Many precious earthen monuments have been lost or heavily damaged by earthquakes.
Peru is a seismic country with a long tradition of building with earth
During the 1970 Huaraz earthquake, around 30,000 persons were killed by their own adobe houses.
The 1970 Huaraz earthquake was the worst tragedy caused by a natural phenomenon in Peru.
The Huaraz earthquake motivated us to start investigating about adobe structures
In the 70s we had very rudimentary testing capabilities
Miguel Corazao designed a tilting platform to test full-scale adobe housing models.
We attempted to find simple reinforcement solutions for adobe houses
Miguel’s research project obtained the 1973 “Sayhuite” Award
We then obtained funds from the governments of the Netherlands and Peru to develop an earthquake engineering lab at the PUCP.
The Antiseismic Structures Laboratory “Cristóbal de Losada y Puga” was inaugurated on October 22, 1979
We are now able to perform more sophisticated tests because we have adequate infrastructure, facilities and equipment.
We have been working since the 1970s to develop earthquake-resistant solutions for earthen construction.
We are studying simple field methods to evaluate soils for adobe construction.
We developed the indirect tension test with adobe sandwiches.

Prof. Julio Vargas observes with great attention an indirect tension test of an adobe sandwich.
The diagonal compression test is used to measure the shear strength of the adobe masonry.
Full scale tests of adobe walls subjected to in-plane and out-of-plane loads are required to estimate their cyclic response.
Shaking table test of full-scale models are the best way to understand seismic response of adobe structures
Act 2

A Life-saving Net
From the beginning it was clear that the adobe walls required seismic reinforcement to achieve some ductility (we reinforce concrete, don’t we?)
The adobe walls will break into pieces during shaking. Therefore some kind of net is required to keep the pieces together and avoid collapse.
There is not enough cane to rebuild thousands of earthen houses after a strong earthquake.

Casma, Ancash, 1970

(NISEE)
Since 2004 we are performing research on the use of synthetic materials to provide seismic reinforcement for earthen structures.
We have explored the use of internal and external reinforcement nets made with plastic.
Adobe walls with plastic reinforcement showed excellent response to cyclic loading.

Internal reinforcement: a net of PVC tubes and plastic mesh

External geomesh reinforcement
Adobe walls with plastic reinforcement showed excellent response to cyclic loading.
In 2005 we developed a joint project with the Getty Conservation Institute to study reinforcement alternatives for earthen construction.
An unreinforced model represented a typical adobe dwelling
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As expected, the unreinforced model collapsed during shaking.

M000 after (D = 130 mm) test
Model M100-T12 was fully reinforced with a polymer mesh (geogrid) and a wooden crown beam.
The geomesh reinforcement was effective to prevent seismic damage.
The model reinforced with geomesh suffered only slight damage after strong shaking

M100-T12 after D = 130 mm test
A cheap plastic mesh was also studied
The plastic mesh kept the structure together
The plastic mesh avoided collapse, but the house was unrepairable after the strong shaking.
Reinforcement made with welded steel mesh covered by cement mortar increases the seismic strength but does not provide ductility.
Conclusions

- Unreinforced earthen constructions will suffer heavy damage or collapse during earthquakes.
- Reinforcement must be provided to protect earthen buildings located in seismic areas.
- Reinforcement should be made of materials compatible with earthen material.
Act 3

What about the people?
We have made attempts to show the users how to build earthquake-resistant adobe houses...
Our work has been recognized worldwide
We know that it is possible to build safe adobe houses in seismic areas

However…

… no one has spontaneously built his adobe house using seismic reinforcement
**Why?**

We think this is because:

1. Inadequate communication methods
2. Additional cost (time and money)
3. Resistance to change
4. Short seismic memory
5. Negative reaction to foreign intervention
The August 15, 2007 Pisco earthquake killed near 600 persons and destroyed almost 75,000 houses, most of then built with adobe.

Many families rebuilt their homes the same way as before.
This tragedy gave us an opportunity to try a different approach to the reconstruction of the affected areas. This approach is based on the philosophy of human development presented by Amartya Sen (1988 Economics Nobel Prize).
According to Sen, development is achieved when people have the capability (or the freedom) to live the way they value.
Many countries attempt to reach development by promoting mainly the economic dimension, with the idea that the remaining freedoms will arrive later…
It is possible to make progress towards development by increasing the capabilities of the communities in dimensions that not require great economical investment.
Many times external aid is inefficient or wasteful
The communities should not be mere recipients of external aid

... they should be agents of their own development
In many developing countries earthen construction is inevitable…

… and it doesn’t make sense to ask the communities to build by themselves improved (safe and healthy) adobe houses
It is necessary to increase the capacity of the communities so that they can build better adobe houses.
Possible steps:

- Development of better reinforcement systems (simpler, cheaper)
- Public education on the vulnerability of traditional adobe construction and the possibility of building better houses
- Development of appropriate communication and training methods
- Implementation of massive construction programs
This is a multidimensional problem. It requires multidimensional and interinstitutional solutions.
After the Pisco earthquake PUCP, CARE-PERÚ and FORSUR joined forces. One objective was to develop a methodology for community training on the construction of safe and sanitary adobe houses.
About 100 builders from the affected areas were trained at the PUCP

Ing. Julio Vargas
Three reinforced adobe houses were built by the communities in Cañete, Chincha and Pisco (9 total)

“Learning by doing”
Several NGOs are now working on a national rural housing program. They have built more than 4000 houses with reinforced adobe.

The Peruvian government is aware of the problem.
The BBC reported 2 years after the Pisco earthquake

Almost 5 years later, Pisco still waits for reconstruction
An interdisciplinary team has developed communication and training tools

Marcial Blondet, Civil engineer
Alvaro Rubiños, Civil engineer
Katherine Chávez, Civil eng. student
Jorge Alencastre, Mechanical engineer
Carla Colona - Communicator
Patricia Ruiz-Bravo - Sociologist
Pablo Quintanilla - Philosopher
Makena Ulfe - Antropologist
Tesania Velasquez - Psychologist

Catholic University of Peru
Department of Engineering
We have developed the following products:

- Adobe Construction Tutorial [www.world-housing.net](http://www.world-housing.net)
- Construction Manual
- Motivational Video
- Technical Video
- Portable Shaking Table
The Portable Shaking Table will be used to make demonstrations to the communities
Katherine has built the first adobe casitas, has performed preliminary system tests…

…and has disappeared! (where are you, Katherine?)
We are committed to working towards safe and decent earthen housing, and stable, well protected earthen monuments all over the world.

Thank you.
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Thank you.